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ENHANCEMENT OF THE FLEXIBLE SPACECRAFT DYNAMICS PROGRAM

FOR OPEN SPACECRAFT

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1.0 SUMMARY

This report describes the modifications and additions made to the Flexible Spacecraft Dynamics (FSD) Program under contract NAS5-28128. The principal addition to the program was the capability to simulate a single axis gimble platform nadir pointing despin control system. The formulation for the single axis gimble equations of motion is a modification of the formulation given in Reference 1. The details of the modifications made to the FSD Program are presented in Section 2. Modifications to existing subroutines are briefly described and a detailed description of new subroutines is given. In addition, the program variables in new labelled COMMON blocks are described in detail. Section 3 gives a description of new input symbols for the FSD Program.

2.0 PROGRAM ADDITIONS AND MODIFICATIONS

2.1 Summary of Modifications by Task

Task 1. Control System for Imager Experiment

A single axis platform on the spacecraft hub with a proportional, integral, and derivative (PID) feedback digital control system has been added to the program. Closed loop nadir pointing from a spinning spacecraft is provided. A first order sensor lag transfer function of the form:

$$\frac{K}{S + \omega}$$

where ω is the bandwidth and K is the sensor gain has been implemented for the nadir error signal. The integrator in the PID has a limiter on it and a zero order hold follows the output of the PID operating at the control rate. The despin motor has coulomb friction and different plus or minus torque limiting values. An inputed computational delay is included in the control system as well as a signal noise generator which can be added to the error signal. Provisions have been made for autonomous scan capability. The platform and control system are able to function concurrently with other platforms and control systems in the program. This capability is operable for INOPT 1 and 2.

Task 2. Internal Torques Generated by Moving Parts

Calculation, printing, and plotting or internal reaction torques generated by moving (rotating) parts on the spacecraft; for example: motor torques in control systems, momentum wheel torque, autonomous scanning, rastering torques, etc. has been added. This capability is operable for INOPT 1 and 2.

Task 3. Autonomous Scan Capability for 2 Axis Scan Platform

Currently, the FSD program has a 2 axis scan platform with close loop control about both axes. Autonomous scanning has been added to the azimuth and elevation axes of the scan platform. This scanning capability is similar to the secondary body rastering option currently in the program.

Task 4. Spacecraft Field Components and External Disturbance Torques Without Attitude Dynamics

For earth pointing systems (INOPT 2) an option has been added to constrain attitude angles to a fixed attitude (nominally roll, pitch and yaw are set to zero or fixed angles) and fly the spacecraft around the orbit. The magnetic field components in spacecraft coordinates and ascension and declination of the sun vector are determind. Also, torques due to aerodrag, solar pressure, gravity gradient, and magnetics are calculated and plotted.

Task 5. Additional Fluid Dampers

Two additional fluid nutation dampers have been added to the FSD program. These dampers are similar to the one that is currently in the program. The dampers can be arbitrarily oriented. The new damper option can be run in a stacked case where initially damping is zero and subsequently it is invoked. The additional dampers will permit wire motion dampers to be simulated concurrently with a nutation dampers as well as other applications. The fluid damper option is operable for INOPT 1 and 2.

2.2 Description of Subroutine Modifications

The modifications made to existing subroutines are briefly described below.

AIRDRG A calculation for aerodynamic torques on the spacecraft hub has been added.

AWREAD Provision for printing the motor torque has been added.

BLK8 Titles have been added for labelling new plotted variables.

DEREQ Calls to new subroutines have been inserted.

ECHOGP Calls inserted for new echo print.

FNDALP Calls to new subroutines have been inserted.

GIMBL1 Modifications for gimble rastering have been inserted.

GIMBL2 Modifications for gimble rastering have been inserted.

GMBLRD Modifications for gimble rastering have been inserted.

GMINIT Modifications for gimble rastering have been inserted.

GPPLOT Calls inserted for new plotted output.

GPSOUT Calls inserted for new printed output.

MAIN Calls to new subroutines have been inserted.

NUMPGE Calls inserted for new state variables.

READGP Calls inserted for new input.

2.3 Description of New Subroutines

The new subroutines are described below.

Subroutine Name:	ADMDUM
Language:	FORTRAN IV
Calling Sequence :	CALL ADMDUM (N, DEL, DEP, DER, UP, DN, FAC, FRQ, TSTOP, L, T, DELMIN)
Purpose :	This multiple entry subroutine controls the program in the no integration, constant attitude simulations.
Labelled Commons Used :	CENVRN, CONSTS, CNBODY, CSTVAL, IMAIN1, IPOOL1, INOMOT, KNERGY, LIBDPR, ORBNEW, OUTTHR, RMGNTC, RPOOL6, SUNVTR, VECTRS, XIN2
Subroutines Called :	ADMIMP, MATMPY, SET, XFIND
Entries :	Calling Sequence : CALL ADMWRP (BUFF, INDEX) Purpose : This entry loads data for plotting into the plot buffer. Calling Sequence : CALL ADMPRN Purpose : This entry provides for printed output using the subroutine SET.

Glossary of Variables :

Symbol	Type	Definition
N	I*4	Number of equations in state vector.
DEL	R*8	Initial integration time step.
DEP (150)	R*8	State vector.
DER (150)	R*8	State vector derivative.
UP (150)	R*8	Integration error bound upper limit.
DN (150)	R*8	Integration error bound lower limit.
FAC	R*8	Time step change factor.
FRQ	R*8	Output record frequency.
TSTOP	R*8	Integration stop time.
L	I*4	Integration control integer.
T	R*8	Integration time.
DELMIN	R*8	Minimum allowable time step.
BUFF (450)	R*4	Plot buffer.
INDEX	I*4	Plot buffer address.

Subroutine Name :	RASTGM
Language :	FORTRAN IV
Calling Sequence :	CALL RASTGM (ANG, ANGD, ANGDD)
Purpose :	RASTGM calculates prescribed angular motion for the two axis gimble.
Labelled Commons Used :	CONSTS, CRSTGM, CSTVAL, IRSTGM, RPOOL1
Subroutines Called :	None.
Entries :	None.

Glossary of Variables

Symbol	Type	Definition
ANG (3)	R*8	Prescribed angular position for two axis gimble platform.
ANGD (3)	R*8	Prescribed angular velocity for two axis gimble platform.
ANGDD (3)	R*8	Prescribed angular acceleration for two axis gimble platform.

Subroutine Name :	RASTSA
Language :	FORTRAN IV
Calling Sequence :	CALL RASTSA (ANG, ANGD, ANGDD)
Purpose :	RASTSA calculates prescribed angular motion for the single axis gimble.
Labelled Commons Used :	CONSTS, CSAGRS, CSTVAL, ISAGRS, RPOOL1
Subroutines Called :	None.
Entries :	None.

Glossary of Variables

Symbol	Type	Definition
ANG (3)	R*8	Prescribed angular position for single axis gimble platform.
ANGD (3)	R*8	Prescribed angular velocity for single axis gimble platform.
ANGDD (3)	R*8	Prescribed angular acceleration for single axis gimble platform.

Subroutine Name :	SAGIM1
Language :	FORTRAN IV
Calling Sequence:	CALL SAGIM1 (SY1, SY2, SY3, CIY)
Purpose :	To add gimble mass properties into system mass properties and set up gimble equations of motion.
Labelled Commons Used :	CONSTS, CSAGIM, SAGMWK, SAGOUT, SAPRPL, SARSOT, ISAGIM, ISAGRS, RPOOL1, VARBLS
Subroutines Called :	MPYMAT, MATV, ADDV, RASTSA

Glossary of Variables

Symbol	Type	Definition
SY1	R*8	$\int Y_1 dm$
SY2	R*8	$\int Y_2 dm$
SY3	R*8	$\int Y_3 dm$
CIY (3,3)	R*8	$CIY(I,J) = \int Y_i Y_j dm$

Subroutine Name :	SAGIM2
Language :	FORTRAN IV
Calling Sequence :	CALL SAGIM2 (ITEST, ZML, ETA, NALP)
Purpose :	To complete calculation of gimble equations of motion and determine gimble accelerations.
Labelled Commons Used :	CSAGIM, DEBUG2, SAGMWK, SAGOUT, HSAGIM, ISAGIM, ISAGRS, RPOOL1, RPOOL3, SARSOT, TRQOUT, VARBLS
Subroutines Called :	MATV, ADDV, MPYMAT, SAGINF, SAGCNT

Glossary of Variables

Symbol	Type	Definition
ITEST	I*4	Internal control word.
ZML(7,7)	R*8	System equations of motion mass and inertia coupling matrix.
ETA (7)	R*8	System acceleration vector.
NALP	I*4	No. of system equations of motion.

Subroutine Name : SAGINF

Language : FORTRAN IV

Calling Sequence : CALL SAGINF (AZIF)

Purpose : To calculate internal spring and damping forces for azimuth equations of motion.

Labelled Commons Used : SAINTF, SAGOUT

Subroutines Called : None

Glossary of Variables

Symbol	Type	Definition
AZIF	R*8	Internal spring and damping moment for azimuth equation of motion.

Subroutine Name :	SAGMRD
Language :	FORTRAN IV
Calling Sequence :	CALL SAGMRD
Purpose :	This subroutine performs input and output tasks for the single axis gimble simulation.
Labelled Commons Used :	CSAGIM, CSAGRS, SAGICS, SAINTF, SAPRPL, ISAGIM, ISAGRS
Subroutines Called :	SETUP, SAPLCS, HVAL, IVAL, FVAL, SET
Entries :	ECHOSA, SAGPLT, SAPRNT

Calling Sequence :	CALL ECHOSA
Purpose :	This entry performs echo printout of the input for the single axis gimble.
Calling Sequence :	CALL SAGPLT (BUFF, INDEX)
Purpose :	This entry provides for writing of output data to be used in printer plots.
Calling Sequence :	CALL SAPRNT
Purpose :	This entry provides for printed output data.

Glossary of Variables

Symbol	Type	Definition
BUFF (450)	R*4	Output vector of plotting variables.
INDEX	I*4	Location in BUFF of last variable used.

Subroutine Name :	SAINIT
Language :	FORTRAN IV
Calling Sequence :	CALL SAINIT
Purpose :	This subroutine does initial calculations for the single axis gimble simulation.
Labelled Commons Used :	ADSTAT, CONSTS, SAGICS, SAGOUT, ISAGIM, ISAGRS, CSAGIM, CSAGRS
Subroutines Called :	DTR312

Glossary of Variables :

Significant variables are defined in labelled common.

Subroutine Name :	SAPLCS		
Language :	FORTRAN IV		
Calling Sequence :	CALL SAPLCS		
Purpose :	This multiple entry subroutine contains all the coding relative to the control system for the single axis gimble platform.		
Labelled Commons Used :	ADSTAT, CONSTS, CSAPCS, CSTVAL, DATOUT, DEBUG2, DRPROT, SAGOUT, HSAGIM, ISAGIM, IMAIN1. INEWR, IPOOL1, MOMENT, OUTTHR, RMAIN1, RMGNTC, RPOOL1, RPOOL5, VARBLS, XIN4		
Subroutines Called :	SETUP, HVAL, FVAL, MATV, SET		
Entries :	Calling Sequence :	CALL NUMSAP (NUMEQS)	
	Purpose :	This entry adds the three sensor transfer function equations to the equation counter.	
	Calling Sequence :	CALL ECHSAC	
	Purpose :	This entry provides for echo printout of the single axis gimble platform control system parameters.	

Calling Sequence :	CALL SACINT (FRQ)
Purpose :	This entry sets the initial values into the DEPEND array.
Calling Sequence :	CALL SACSNR
Purpose :	This entry provides for calculation of the sensor transfer function derivatives.
Calling Sequence :	CALL SAGCNT (AZCNT)
Purpose :	This entry calculates the motor torques for the single axis gimble drive motor.
Calling Sequence :	CALL SAPIDC (IPRFLG)
Purpose :	This entry calculates the output of the PID controller for the single axis gimble. axis
Calling Sequence :	CALL SAPWRP (BUFF, INDEX)
Purpose :	This entry loads data for plotting into the plot buffer.
Calling Sequence :	CALL SAPPRN
Purpose :	This entry provides for printed output using the subroutine SET.

Glossary of Variables

Symbol	Type	Definition
NUMEQS	I*4	The number of equations in the state vector.
FRQ	R*8	Frequency of integrator returns to MAIN by ADMIMP.
AZCNT	R*8	Gimble drive motor torque.
IPRFLG	I*4	Internal control for frequency of printed output records.
BUFF (450)	R*4	Output vector for plotted output.
INDEX	I*4	Location in BUFF of last entered data.

Subroutine Name :	TRQORD
Language :	FORTRAN IV
Calling Sequence :	CALL TRQORD
Purpose :	To provide for output of internal reaction torques.
Labelled Commons Used :	ITRQOT, TRQOUT
Subroutines Called :	SETUP, SET
Entries :	Calling Sequence : CALL TRQPLT (BUFF, INDEX)
	Purpose : To load variables for plotting.
	Calling Sequence : CALL TRQPRN
	Purpose : To provide for printed output using the subroutine SET.

Glossary of Variables

Symbol	Type	Definition
BUFF (450)	R*4	Output vector for plotted output.
INDEX	I*4	Location in BUFF of last entered data.

Subroutine Name :	VDMPRD
Language :	FORTRAN IV
Calling Sequence :	CALL VDMPRD
Purpose :	To provide for the simulation and torques generated by additional viscous ring dampers.
Labelled Commons Used :	ADSTAT, CONSTS, DEBUG2, IMAIN1, OUTAVD, RPOOL1, RAVSCS, XIN4
Subroutines Called :	SETUP, FVAL, HVAL, IVAL, SET

Entries :	Calling Sequence :	CALL NUMVDE (NUMEQS)
	Purpose :	To augment state vector size for viscous damper variables.
	Calling Sequence :	CALL ECHOVD
	Purpose :	To provide echo print of viscous damper parameters.
	Calling Sequence :	CALL VDINIT
	Purpose :	To initialize state vector for viscous damper initial conditions.
	Calling Sequence :	CALL VISCS2 (IT, ZML, OM, OMD, DEP, DER, CMP)
	Purpose :	To calculate damper variable derivatives and damper reaction moments on the system.
	Calling Sequence :	CALL VDPRNT
	Purpose :	To load print variables into print buffer for printing.

Glossary of Variables

Symbol	Type	Definition
NUMEQS	I*4	The number of equations in the state vector.
IT	I*4	Internal control integer.
ZML (7,7)	R*8	System mass and inertia coupling matrix.
OM (3)	R*8	System angular velocity.
OMD (3)	R*8	System angular acceleration.
DEP (150)	R*8	State vector.
DER (150)	R*8	State vector derivative.
CMP (3,2)	R*8	Damper reaction torques.

2.4 Description of New Labelled Common

The new labelled COMMON blocks are described below.

Common Block Name : COMMON/CRSTGM/DELA(3), TAUA(4,3), ANGO(3), ADDO(3), TC(3), TTAB(4,3)

Used in Subroutines: GMBLRD, GMINIT, RASTGM

Variables:

Fortran Name	Type	Units	Description
DELA (3)	R*8	Deg.	Angular motion to be performed in a single cycle of rastering motion.
TAUA(4,3)	R*8	Sec.	Time increments for rastering cycle.
ANGO (3)	R*8	Deg.	Initial angle for start of rastering cycle.
ADDO (3)	R*8	Deg./Sec.^{2}	Peak rastering acceleration.
TC (3)	R*8	Sec.	Total cycle time for each axis.
TTAB (4,3)	R*8	Sec.	Cycle times.

Common Block Name : COMMON/CSAGIM/AZIN (3,3), AZAX(3), AZCG(3), AZMS, AZYY(3,3) AZIAX(3,3), ZZAZ(3,3)

Used in Subroutine :SAGM, SAINIT, SAGIM1, SAGIM2

Variables :

Fortran Name	Type	Units	Description
AZIN(3,3)	R*8	Slug-Ft^2	Moment of inertia of gimble platform about its own center of mass.
AZAX(3)	R*8	Ft.	Location of gimble axis in body frame.
AZCG(3)	R*8	Ft.	Location of platform center of mass in platform reference frame.

Fortran Name	Type	Units	Description
AZMS	R*8	Slugs	Mass of platform.
AZYY(3,3)	R*8	Slug-Ft^2	$\int Z_i Z_J dm$ for platform about its center of mass.
AZIAX(3,3)	R*8	Slug-Ft^2	$\int Z_i Z_J dm$ for platform about the azimuth frame origin.
ZZAZ(3,3)	R*8	Slug-Ft^2	$\int Z_i Z_J dm$ for gimble platforms about frame origin.

Common Blck Name : COMMON/CSAGRS/DELA(3), TAUA(4,3), ANGO(3), ADDO(3), TC(3), TTAB(4,3)

Used in Subroutines : RASTSA, SAGMRD, SAINIT

Variables :

Fortran Name	Type	Units	Description
DELA(3)	R*8	Deg.	Angular motion to be performed in a single cycle of rastering motion.
TAUA(4,3)	R*8	Sec.	Time increments for rastering cycle.
ANGO(3)	R*8	Deg.	Initial angle for start of rastering cycle.
ADDO(3)	R*8	Deg/Sec^2	Peak rastering acceleration.
TC(3)	R*8	Sec.	Total cycle time for each axis.
TTAB(4,3)	R*8	Sec.	Cycle times.

Common Block Name : COMMOM/CSAPCS/PCSPRM(100), IPLTCS(20)

Used in Subroutine: SAPLCS

Variables:

Fortran Name	Type	Units	Description
PCSPRM(100)	R*8	Varies	Parameters used in the single axis gimble platform control system.
IPLTCS(20)	I*4	N.A.	Integer control words for for single axis gimble platform control system.

Common Block Name : COMMON/INOMOT/NOINTG, NOIOUT(20)

Used in Subroutines: ADMDUM, READGP

Variables:

Fortran Name	Type	Units	Description
NOINTG	I*4	N.A.	Control integer for simulation without integration.
NOIOUT(20)	I*4	N.A.	Control integers for output of spacecraft external torques.

Common Block Name : COMMON/IRSTGM/IRAST, IARST(3), IRSCY(3)

Used in Subroutines: GIMBL1, GIMBL2, GMBLRD, GMINIT, RASTGM

Variables:

Fortran Name	Type	Units	Description
IRAST	I*4	N.A.	Control word to invoke prescribed rastering motion for two axis gimble.
IARST(3)	I*4	N.A.	Control word to specify type of rastering cycle.
IRSCY(3)	I*4	N.A.	Number of cycles of rastering motion to be performed.

Common Block Name: COMMON/ISAGIM/IGMBL, NAZIM, NAI

Used in Subroutines: SAGMRD, SAINIT, SAGIM1, SAGIM2, SAPLCS

Variables:

Fortran Name	Type	Units	Description
IGMBL	I*4	N.D.	Control word for gimble simulation. IGMBL 0 No gimble simulation. IGMBL 1 Single axis gimble simulation.
NAZIM	I*4	N.D.	Location in the state vector of the gimble angle.
NAI	I*4	N.D.	Location in the state vector of the gimble angular velocity.

Common Block Name: COMMON/ISAGRS/IRAST, IARST(3), IRSCY(3)

Used in Subroutines: RASTSA, SAGIM1, SAGIM2, SAGMRD, SAINIT

Variables:

Fortran Name	Type	Units	Description
IRAST	I*4	N.A.	Control word to invoke prescribed rastering motion for single axis gimble.
IARST(3)	I*4	N.A.	Control word to specify type of rastering cycle.
IRSCY(3)	I*4	N.A.	Number of cycles of rastering motion to be performed.

Common Block Name: COMMON/ITRQOT/IOUTPT(150)

Used in Subroutines: TRQORD

Variables:

Fortran Name	Type	Units	Description
IOUTPT(150)	I*4	N.A.	Vector of control integers for reaction torque output.

Common Block Name: COMMON/OUTAVD/OMEGL(2), VSUBL(2), MSUBM(3,2)

Used in Subroutines: VDMPRD

Variables:

Fortran Name	Type	Units	Description
OMEGL(2)	R*8	Rad./Sec.	Angular velocity of damping fluid.
VSUBL(2)	R*8	Ft./Sec.	Velocity of damping fluid.
MSUBM(3,2)	R*8	Ft./Sec.	Damping torque from fluid damper.

Common Block Name: COMMON/RAVSCS/NSUBX(3,2), YARRAY(3,2), RADTBE(2),
VISCTY(2), RADRNG(2), DENSTY(2), JARRAY(3,2)
SSUBY(2), OMLI(2), ISUBD(2), VUP(2), VDN(2), NVD

Used in Subroutines: VDMPRD

Variables:

Fortran Name	Type	Units	Description
NSUBX(3,2)	R*8	N.D.	Unit vectors in direction of damper axis.
YARRAY(3,2)	R*8	Ft.-Lbs.	Initial components of torque along damper axis.
RADTBE(2)	R*8	In.	Radius of damper tubes.
VISCTY(2)	R*8	Centi Stokes	Viscosity of liquid.
RADRNG(2)	R*8	In.	Radius of damper ring.
DENSTY(2)	R*8	$Lbs./Ft^3$	Fluid density.
JARRAY(3,2)	R*8	-	Initial values for bessel functions.
SSUBY(2)	R*8	-	Damping torque.
OMLI(2)	R*8	Deg/sec.	Initial fluid angular velocity.
ISUBD(2)	R*8	$Slug-Ft^2$	Fluid moment of inertia.
VUP(2)	R*8	-	Integration upper bound.
VDN(2)	R*8	-	Integration lower bound.
NVD	I*4	N.A.	Number of additional viscous ring dampers.

Common Block Name: COMMON/SAGICS/AZIMO, ROLLO, ELEVO, AZIMI, AZIMID,
GMUP(2), GMDN(2)

Used in Subroutines: SAGMRD, SAINIT

Variables:

Fortran Name	Type	Units	Description
AZIMO	R*8	Deg.	Rotation about the three axis in a 3-1-2 rotation from the body frame to the gimble motion reference frame.

Fortran Name	Type	Units	Description
ROLLO	R*8	Deg.	Rotation about the one axis in a 3-1-2 rotation from the body frame to the gimble motion reference frame.
ELEVO	R*8	Deg.	Rotation about the two axis in a 3-1-2 rotation from the body frame to the gimble motion reference frame.
AZIMI	R*8	Deg.	Initial angular position of the gimble platform.
AZIMID	R*8	Deg/Sec	Initial angular velocity of the gimble platform.
GMUP(2)	R*8	RAD Rad/Sec	Integration upper bounds for gimble rotation and rotation rate.
GMDN(2)	R*8	RAD Rad/Sec	Integration lower bounds for gimble rotation and rotation rate.

Common Block Name : COMMON/SAGMWK/DELT, GAMGM(6), GMRHS, DI, DIGAM(6)
DZML(6,6), YAZB(3)

Used in Subroutines: SAGIM1, SAGIM2

Variables

Fortran Name	Type	Units	Description
DELT	R*8	$Slug/Ft^2$	Diagonal coefficient for platform acceleration.
GAMGM(6)	R*8	Varies	Coupling matrix between platform acceleration and system translational and rotational accelerations.
GMRHS	R*8	Ft-Lbs.	Torques for platform equation of motion.
DI	R*8	---	Inverse of $[\delta] = [\delta]^{-1}$
DIGAM (6)	R*8	---	$[\delta]^{-1}[\gamma]$
DZML(6,6)	R*8	---	$[\gamma][\delta]^{-1}[\gamma]^T$
YAZB(3)	R*8	Ft.	Location of the axis measured in the platform reference frame.

Common Block Name: COMMON/SAGOUT/AZ, AZD, B(3,3), BO(3,3), C(3,3), BOBC(3,3), YAZ(3), ZAZM(3)

Used in Subroutine: SAGINF, SAINIT, SAGIMI, SAGIM2, SAPLCS

Variables

Fortran Name	Type	Units	Description
AZ	R*8	Rad.	Angular position of the gimble platform.
AZD	R*8	Rad/Sec.	Angular velocity of the gimble platform.
B(3,3)	R*8	N.D.	Transformation matrix from the azimuth platform reference frame to the gimble motion reference frame.
BO(3,3)	R*8	N.D.	Transformation matrix from the gimble motion reference frame to the body frame.
BOB(3,3)	R*8	N.D.	$[BOB] = [BO][B]$
C(3,3)	R*8	N.D.	Transformation matrix from the elevation platform reference frame to to the azimuth platform reference frame.
BOBC(3,3)	R*8	N.D.	$[BOB][C]$
YAZ(3)	R*8	Ft.	Position of the azimuth gimble CG from the body frame origin measured in the body frame.
ZAZM(3)	R*8	Slug-Ft.	First moment of the gimble mass about the azimuth gimble frame origin.

Common Block Name: COMMON/SAINTF/GMK1, GMK2, GMDMP, GMSTP

Used in Subroutines : SAGINF, SAGMRD

Variables

Fortran Name	Type	Units	Description
GMK1	R*8	Ft-Lbs/Rad	Spring constant for gimble suspension.
GMK2	R*8	Ft-Lbs/Rad	Stop spring constant for gimble suspension.
GMDMP	R*8	Ft-Lb-Sec/Rad	Viscous damping constant for gimble suspension.
GMSTP	R*8	Rad	Stop angle for gimble suspension.

Common Block Name: COMMON/SAPRPL/GMBAZ, GMBAZD

Used in Subroutines : SAGIM1, SAGMRD

Variables

Fortran Name	Type	Units	Description
GMBAZ	R*8	Deg.	Output angular position of gimble platform.
GMBAZD	R*8	Deg/Sec.	Output angular velocity of gimble platform.

Common Block Name : COMMON/SARSOT/AZDD, SARHST(3), SARHSR(3)

Used in Subroutines: SAGIM1, SAGIM2

Variables

Fortran Name	Type	Units	Description
AZDD	R*8	Rad/Sec^2.	Platform angular acceleration during rastering cycle.
SARHST(3)	R*8	Lbs.	Inertial forces on system translation due to platform rastering motion.
SHRHSR(3)	R*8	Ft.-Lbs.	Inertial torques on system rotation due to platform rastering motion.

Common Block Name : COMMON/TRQOUT/OUTTRQ(150)

Used in Subroutines: TRQORD, WHREAD, AWREAD

Variables

Fortran Name	Type	Units	Description
OUTTRQ(150)	R*8	Ft-Lbs.	Vector or reaction torques for output.

3.0 DESCRIPTION OF NEW INPUT AND OUTPUT

3.1 Single Axis Platform Simulation Input and Output

Fortran Symbol	Type	Preset Value	Description
ISAGM	I*4	0	Control word for single axis platform simulation. ISAGM 0 No platform simulated. ISAGM 1 Platform simulated.
SAIN(3,3)	R*8	0.0D0	Moments of inertia of the single axis platform about its own center of mass(slug-ft^2).
SAAX(3)	R*8	0.0D0	Position vector in the body frame to the origin of the platform motion reference frame. This position is a point on the motion axis (ft.).
SACG(3)	R*8	0.0D0	Position vector to the platform center of mass in the platform motion reference frame (ft.).
SAMS	R*8	0.0D0	Mass of the platform (slugs).
SAK1	R*8	0.0D0	Spring constant for single axis gimble suspension. Applies to angles less than the stop angle (ft-lb/rad).
SAK2	R*8	0.0D0	Spring constant for single axis platform suspension. Applies to angles greater than the stop angle (ft-lb/rad).
SAGDM	R*8	0.0D0	Viscous damping constant for single axis platform suspension (ft-lb-sec/rad).

Fortran Symbol	Type	Preset Value	Description
SASTP	R*8	0.0D0	Stop angle for single axis platform suspension (rad).
SAAZO	R*8	0.0D0	Rotation about the three axis in a 3-1-2 angle set from the main body frame to the platform motion reference frame (deg). NOTE: The gimble motion reference frame is a main body fixed frame.
SARLO	R*8	0.0D0	Rotation about the one axis in a 3-1-2 angle set from the main body frame to the platform motion reference frame (deg).
SAELO	R*8	0.0D0	Rotation about the two axis in a 3-1-2 angle set from the main body frame to the platform motion reference frame (deg).
SAAZI	R*8	0.0D0	Initial azimuth angular position for the single axis platform (deg).
SAAZID	R*8	0.0D0	Initial azimuth angular velocity for the single axis platform (deg/sec).
SAUP(2)	R*8	1.0D-3	Integration upper bounds for platform angle and angular rate. SAUP(1) (rad). SAUP(2) (rad/sec).
SADN(2)	R*8	1.0D-5	Integration lower bounds for platform angle and angular rate. SADN(1) (rad). SADN(2) (rad/sec).

Single Axis Platform Rastering Input

Fortran Symbol	Type	Preset Value	Description
ISAGRS	I*4	0	Control word to invoke prescribed rastering motions for single axis platform. ISAGRS = 0 No rastering. ISAGRS = 1 Rastering prescribed.
ISARST(1)	I*4	0	Control word to specify type of rastering cycle to be invoked on single axis platform. ISARST(1) = 0 No motion. ISARST(1) = 1 Motion of Type 1. ISARST(1) = 2 Motion of Type 2. NOTE: The types of motion cycles are shown in Reference 2.
ISASCY	I*4	0	Number of cycles of rastering motion to be performed.
SADELA	R*8	0.0D0	Angular motion to be performed during a single cycle of rastering motion (deg.).
SATAUA (4,3)	R*8	0.0D0	Time increments to define rastering cycle. SATAUA (1,1) = T_1 SATAUA (2,1) = T_2 SATAUA (3,1) = T_3 SATAUA (4,1) = T_4
SAAN20	R*8	0.0D0	Initial angle for the start of the rastering cycle (deg.).

Plotting locations for single axis platform motion variables

Fortran Symbol	Description
KPLOTS(341)	Angular position for the single axis platform.
KPLOTS(342)	Angular rate for the single axis platform.

Single Axis Platform Printed Output

Fortran Symbol	Description	Units
GMBL AZ	Platform azimuth angle	Deg.
GMBL AZD	Platform azimuth angular velocity	Deg/Sec.

3.2 Single Axis Platform Nadir Pointing Control System Input and Output

Fortran Symbol	Type	Preset Value	Description
ISAPCS (1-20)	I*4	0	Control words for gimble platform control system simulation.
ISAPCS (1)			Control word to invoke the single axis platform control system option. ISAPCS(1) 0 No control system. ISAPCS(1) 1 Control system. NOTE: If a control system is invoked the single axis platform simulation must also be invoked.
ISAPCS (3)			Control word for guassian noise transfer function for the three axes of the nadir sensor. ISAPCS (3) 0 No transfer function ISAPCS (3) 1 Transfer function.

Single Axis Platform Nadir Pointing Control System (continued)

Fortran Symbol	Type	Preset Value	Description
ISAPCS (4)			Number of measurement samples to be averaged for smoothing of sensor output. ISAPCS(4) N average N samples N 1
ISAPCS (5-20)			Not used.
SACSPM (100)	R*8	0.0D0	Platform control system parameters.
SACSPM (1-9)			Not used.
SARSPM (10)			Sampling time for PID digital controller (sec).
SACSPM (11)			Quantatisational level for platform position (rad).
SACSPM (12)			PID integrator upper saturation limit (rad).
SACSPM (13)			PID integrator lower saturation limit (rad).
SACSPM (14)			PID proportional gain K_p
SACSPM (15)			PID integrator gain K_I
SACSPM (16)			PID derivative gain K_D
SACSPM (17-29)			Not used.
SACSPM (30)			Integration upper bound for sensor first order lag transfer function.
SACSPM (31)			Integration lower bound for sensor first order lag transfer function.
SACSPM (32)			Sensor one axis bandwidth.
SACSPM (33)			Sensor two axis bandwidth.
SACSPM (34)			Sensor three axis bandwidth.
SACSPM (35)			Sensor sampling rate (sec).
SACSPM (36)			Computational delay (sec).
SACSPM (37-40)			Not used.
SACSPM (41)			Single axis platform amplifier gain K_A.

Single Axis Platform Nadir Pointing Control System (continued)

Fortran Symbol	Description
SACSPM (42)	Platform motor torque constant K_T .
SACSPM (43)	Platform back EMF constant K_B.
SACSPM (44)	Platform motor torque upper limit L_1 (ft-lbs).
SACSPM (45)	Platform motor torque lower limit L_2 (ft-lbs).
SACSPM (46)	Platform coulomb friction torque constant (ft-lbs).
SACSPM (47)	Platform minimum angular rate for coulomb friction torque (rad/sec).
SACSPM (48)	Platform voltage bias.
SACSPM (49-79)	Not used.
SACSPM (80)	Amplitude of sinusoidal noise added to one axis sensor measurement (gauss).
SACSPM (81)	Amplitude of sinusoidal noise for two axis (gauss).
SACSPM (82)	Amplitude of sinusoidal noise for three axis (gauss).
SACSPM (83)	Phase of sinusoidal noise added to one axis sensor measurement (deg).
SACSPM (84)	Phase of sinusoidal noise for two axis (deg).
SACSPM (85)	Phase of sinusoidal noise for three axis (deg).
SACSPM (86)	Frequency of sinusoidal noise added to one axis magnetometer measurement (cps).

Single Axis Platform Nadir Pointing Control System (continued)

Fortran Symbol	Description
SACSPM (87)	Frequency of sinusoidal noise for two axis (cps).
SACSPM (88)	Frequency of sinusoidal noise for three axis (cps).
SACSPM (89)	Not used.
SACSPM (90-95)	Used internally. Not input.
SACSPM (96-100)	Not used.

Plotting Locations for Platform Control System Variables

Input Symbol	Description
KPLOTS (343)	Output of first order lag transfer function for sensor one axis.
KPLOTS (344)	Output of first order lag transfer function for sensor two axis.
KPLOTS (345)	Output of first order lag transfer function for sensor three axis.
KPLOTS (346)	Position error output.
KPLOTS (347)	PID digital controller output.
KPLOTS (348)	Platform drive motor torque.

Single Axis Platform Control System Printed Output

Fortran Symbol	Description	Units
VNADIR1 VNADIR2 VNADIR3	Filtered body frame components of earth. Nadir pointing unit vector.	N.D.
AZIM ERR	Gimble platform azimuth error angle.	deg.
AZIM PID	Gimble platform azimuth PID output.	Depends on PID gain constants
AZIM MOT	Gimble platform azimuth motor torque.	ft-lbs

3.3 Internal Torque Input and Output

Fortran Symbol	Type	Preset Value	Description
IOUTPT (150)	I*4	0	Control for output of internal reaction torques for reaction controls
IOUTPT (1)			Control word to invoke reaction torque output
			IOUTPT (1) 0 No output
			IOUTPT (1) 1 Output
IOUTPT (2)			Location of reaction torques
			For IWHEEL 1 IOUTPT(2) 1
			For IAMPRM(1)1 IOUTPT(2) 4
			For IAMWH(1) 1 IOUTPT(2) 7
IOUTPT (3)			Location of control motor torques
			For IAMPRM(1) 1 IOUTPT(3) 14
			For IAMWH(1) 1 IOUTPT(3) 17

Plotting Locations for Internal Torques

Input Symbol	Description
KPLOTS (358)	Reaction torque on body 1 axis.
KPLOTS (359)	Reaction torque on body 2 axis.
KPLOTS (360)	Reaction torque on body 3 axis.
KPLOTS (361)	Motor torque on 1 axis.
KPLOTS (362)	Motor torque on 2 axis.
KPLOTS (363)	Motor torque on 3 axis.

Internal Torque Printed Output

Fortran Symbol	Description	Units
TORQUE 1 TORQUE 2 TORQUE 3	Reaction torques acting on body.	Ft-Lbs.
MT TRQ 1 MT TRQ 2 MT TRQ 3	Control motor drive torques on reaction wheels.	Ft-Lbs.

3.4 Autonomous Scan Capability for Two Axis Scan Platform Input

Fortran Symbol	Type	Preset Value	Description
IGMRST	I*4	0	Control word to invoke prescribed scan motions for two axis gimble. IGMRST = 0 No autonomous scan. IGMRST = 1 Autonomous scan.
IGARST (3)	I*4	0	Control word to specify type of scan cycle to be invoked on each axis. IGARST(I) = 0 No motion. IGARST(I) = 1 Motion of type 1. IRARST(I) = 2 Motion of type 2. I = 1 or 3 I = 1 motion about the 3 axis. I = 3 motion about the 2 axis. NOTE: The types of motion cycles are shown in reference 2
IGRSCY (3)	I*4	0	Number of cycles of scan motion to be performed on each axis.
GMDELA (3)	R*8	0.0D0	Angular motion to be performed during a single cycle of scan motion for each axis (deg).
GMTAUA (4,3)	R*8	0.0D0	Time increments to define scan cycle for each axis See reference 2. GMTAUA (1,I) = T_1 GMTAUA (2,I) = T_2 GMTAUA (3,I) = T_3 GMTAUA (4,I) = T_4
GMAN20 (3)	R*8	0.0D0	Initial angle for the start of the scan cycle (deg.).

Output

There is no special output for rastering of the two axis scan platform other than the standard output for the platform motion.

3.5 Field Components and Torques without Attitude Dynamics Input and Output

Fortran Symbol	Type	Preset Value	Description
NOINTG	I*4	0	Control word to bypass integration of equations of motion. NOINTG 0 Integration carried out. NOINTG 1 No integration.
NOIOUT (20)	I*4	0	Control words to invoke printed output of external torques. NOIOUT(1) 0 No gravity gradient torques. NOIOUT(1) 1 Print gravity gradient torques. NOIOUT(2) 0 No solar pressure torques. NOIOUT(2) 1 Print solar pressure torques. NOIOUT(3) 0 No aerodynamic pressure torques. NOIOUT(3) 1 Print aerodynamic pressure torques. NOTE: The control words NOIOUT (1), (2), or (3) will control printing without regard to NOINTG .

Plotting Locations for External Torques

Input Symbol	Description
KPLOTS (349)	Gravity gradient moment on 1 axis.
KPLOTS (350)	Gravity gradient moment on 2 axis.
KPLOTS (351)	Gravity gradient moment on 3 axis.
KPLOTS (352)	Solar pressure moment on 1 axis.
KPLOTS (353)	Solar pressure moment on 2 axis.
KPLOTS (354)	Solar pressure moment on 3 axis.
KPLOTS (355)	Aerodynamic pressure moment on 1 axis.
KPLOTS (356)	Aerodynamic pressure moment on 2 axis.
KPLOTS (357)	Aerodynamic pressure moment on 3 axis.

External Torque Printed Output

Fortran Symbol	Description	Units
GG MOM 1 GG MOM 2 GG MOM 3	Gravity gradient body frame.	Ft-Lbs
SP MOM 1 SP MOM 2 SP MOM 3	Solar pressure body frame components of torque.	Ft-Lbs
AD MOM 1 AD MOM 2 AD MOM 3	Air drag body frame components of torque.	Ft-Lbs

3.6 Additional Fluid Dampers Input and Output

Input

Fortran Symbol	Type	Preset Value	Description
NVDMPR	I*4	0	Control word to simulate additional viscous ring nutation damper. NVDMPR = 0 No dampers simulated. NVDMPR = 1 One damper simulated. NVDMPR = 2 Two damper simulated.
VDVCTY (2)	R*8	0.0D0	Kinematic viscosity of liquid in nutation damper (centistokes).
VDRDTB (2)	R*8	0.0D0	Radius of nutation damper tube (inches).
VDRDRN (2)	R*8	0.0D0	Radius of nutation damper ring (inches).
VDDNTY (2)	R*8	0.0D0	Density of fluid in nutation damper (lb/ft^3).
VDAXIS (3,2)	R*8	0.0D0	Components of unit vector in direction of ring axis.
VDVARY (3,2)	R*8	0.0D0	Initial components of torque exerted by the liquid upon the satellite, directed along the damper ring axis (ft/lbs).
VDOMGL (2)	R*8	0.0D0	Initial spatial average angular velocity of the liquid realtive to the ring (deg/sec).
VDJARY (3,2)	R*8	0.0D0	

Fluid Damper Printed Output

Fortran Symbol	Description	Units
OMEGL	Spatial average angular velocity of the nutation damper fluid relative to the body (INOPT = 1 only)	deg/sec
VSUBL	Average linear velocity of the nutation damper fluid relative to the damper tube wall (INOPT = 1 only)	ft/sec
MSUBM1 MSUBM2 MSUBM3	Body frame components of torque exerted by the nutation damper fluid upon the satellite (INOPT = 1 only)	ft-lb

4.0 REFERENCE

1) Final Report for MAS5-11803, Mod. 8, June 1971, Avco Systems Division, Wilmington, Massachusetts.

2) A Users Guide to the Flexible Spacecraft Dynamics and Control Program V, July 1984, Joseph V. Fedor, NASA X-712-84-8.